Ц Т. Нагирнер

National Aeronautics and Space Administration
Goddard Space Flight Center
Contract No.NAS-5-12487

ST-AM-GM-10636

FEATURES OF PLANETARY DISTRIBUTION OF OZONE ACCORDING TO OBSERVATIONS FROM AES

by

V. A. Iozenas
V. A. Krasnopol'skiy
A. P. Kuznetsov
A. I. Lebedinskiy

(USSR)

FACILITY FORM 602

N67-33867	
(ACCESSION NUMBER)	(THRU)
9	1
(PAGES)	(CODE)
CR-87182	13
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

14 AUGUST 1967

ST-AM-GM-10636

FEATURES OF PLANETARY DISTRIBUTION OF OZONE

ACCORDING TO OBSERVATIONS FROM AES

Presented by A. I. Lebedinskiy*
at X Plenary Meeting of COSPAR
LONDON, ENGLAND, 24-29 July 1967

by V. A. Iozenas,
V. A. Krasnopol'skiy
A. P. Kuznetsov &
A. I. Lebedinskiy

ABSTRACT

Ultraviolet spectra of solar radiation reflected from the Earth's atmosphere, were measured in April 1965 and June 1966 from two Earth's artificial satellites (AES). The optical axis of the spectrophotometer was at an angle of 7° to the direction to nadir. The observation time amounted to 7 days.

Some 45 spectra with 15 A resolution were obtained in the 3070-2250 A and 3300-2500 A wavelength ranges for each passage over the sunlit side of the Earth, respectively in the first and second experiments. The material obtained was used for studying the planetary distribution of ozone. The latter is not uniform: a great number of local extremes of 2 to 3000 km dimensions were observed. Some of these extremes were regularly observed for three days. The mean planetary distribution of ozone shows a latitude dependence corresponding to the decrease in ozone content in the upper atmosphere in approaching high latitudes. The latitude dependence is somewhat different at various altitudes. A 20 to 30 percent decrease in ozone concentration was observed in the course of one experiment within a region of 10000 km characteristic dimension. In a day this effect was somewhat weakened, and the middle part of the region of decreased concentration shifted westward by about 2000 km. On the third day the ozone depression became quite insignificant. The appearance of this depression coincided with the sudden commencement of the magnetic storm of 17 April 1965.

*
* *

In order to investigate the planetary distribution of ozone, ultraviolet spectrophotometers for measuring the Earth-s atmosphere-reflected solar radiation were installed on board two artifical satellites of the Earth (AES).

---

* from preprint obtained at the conference

The first experiment was carried out in April 1965. Spectra in the 3070 -2250 A were detected during this experiment. During the second experiment in June 1965 the measured spectra were in the 3300 -2500 A range. The resolution of the instruments was determined in both cases by the width of the window, and was 14 A. The optical axes of the devices were directed almost to nadir, forming with the vertical an angle of 7°. The detection period of a single spectrum was somewhat less than one minute. The double monochromators constituting the instruments are described in detail in [1].

The instruments were calibrated by means of a hydrogen lamp and a standard incandescent lamp,calibrated at the Shternberg Astronomical Institute using the G. F. Sitnik's method of blackbody [2]. The dependence of the aboslute sens tivity of the instruments on wavelength was determined from the calibrations; the disagreement in the results obtained for each lamp was found to be insignificant. The calibration for wavelengths was performed by means of mercury spectrum.

The spectra were registered in each experiment for about 3 and one half days. The number of obtained atmsopheric spectra was $\sim$ 700. The device operational in June 1966 recorded also atmospheric spectra at horizon ($\sim$ $\sim$ 1000 spectra) and the spectra of solar radiation. When registering the spectra at horizon the optical axis of the device was directed approximately toward the visible horizon using a subsidiary mirror. When registering the solar spactra the entire visual field of the device was filled with sunlit frozen glass. Since the orientation of the instrument with respect to the Sun was known, the registration of solar spectra was performed with the view of checking the variations in instrument's response in flight and allowed the atmospheric albedo to be obtained by direct comparison of instrument's counts when observing the Sun and to nadir. Besides, this problem is of an independent interest both in connection with the possible variations of solar radiation and because the photoelectric measurements of the solar spectrum have not been carried out as yet.

The spectrograms were processed taking into account the nonlinearity of low signals' output, the noises in the device and the dependence of the sensitivity on wavelength. The methods of processing and calibrating are described at further length in ref. [3], where a typical atmospheric spectrum is shown in the equatorial plane, its features being discussed. When processing the spectra beyond the equatorial zone, it is necessary to insert a correction for hhe dependence of device's sensitivity on light polarization, which was easy to realize since the instrument's slot was oriented perpendicularly to orbit plane. During the experiments the noises in the devices exceeded considerably those observed in laboratory. As it turned out, this increase was caused by cosmic radiation background which may be found on the basis of the type of noise and its increase at high latitudes and near the Brazilian magnetic anomaly.

The measured atmospheric spectra varied not only with the zenithal angle of the Sun and the geographic latitude, but also from point to point. According to the material of 1965 experiment the curves of atmospheric radiation intensity were plotted in seven wavelengths and the characteristic constants of ozone concentration decrease with altitude were plotted for each of the 52 orbits [4]. The local inhomogeneities of the atmospheric albedo, which may be traced at several wavelengths, are seen from these curves, which reflect the changes in ozone concentration at various altitudes.

However, the local inhomogeneities are easier to analyze when the instrument's readings in one or several wavelengths are plotted for the same geographic parallel. In this case the neighboring points correspond to the neighboring orbits.

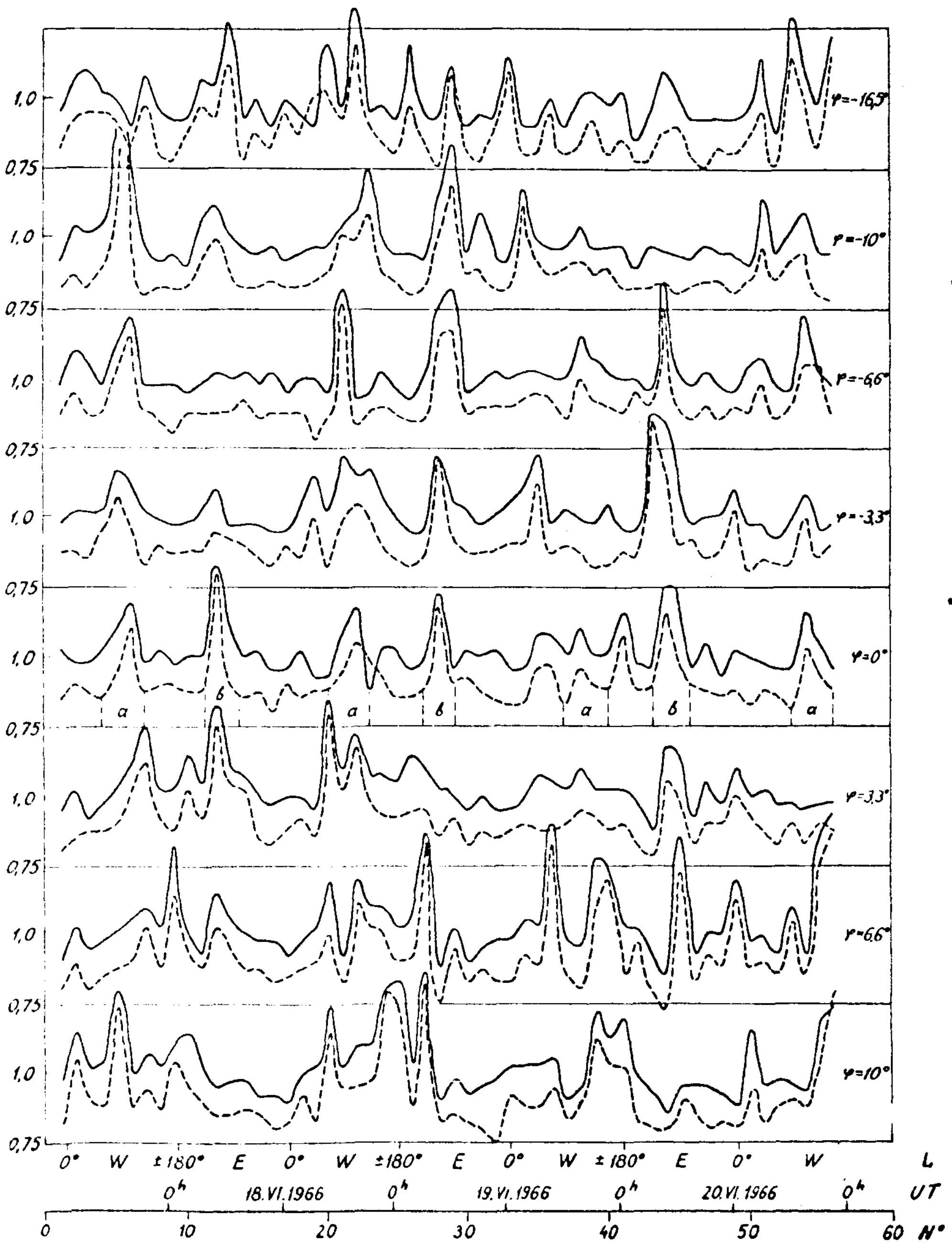

Fig.1. Dependence of the intensity in relative units for the wavelengths λ = 2950 Å and λ = 2930 Å at various latitudes ϕ on the number of orbits (N) (lower scale), universal time (U.T.) (middle scale), and geographic longitude L (upper scale). The data refer to the experiment carried out in June 1966

Fig.1 is such a pattern for a certain set of latitudes on the basis of the experimental material of 1966. The counts are shown in relative units; the geographic longitude and the measurement times are plotted along the horizontal axis. In this diagram the albedo fluctuations from point to point are about 15 - 25 percent. As calculation shows [5], these fluctuations are determined for λ = 2950 A by approximately the same percentage of changes in the ozone content above the level of 30 km.

It may be seen that the albedo dependence for the same latitude shows a number of maxima and minima; some of them (a, b) were maintained for a period of three days during which the observations were carried out. The positions of other extremes varied during this period or gradually vanished. It should be noted that the albedo peak or the ozone content minimum is a more characteristic detail than the albedo minimum. In Fig.1 the local extremes recur at the neighboring latitudes that correspond to the neighboring spectra on a single orbit, the distance between them being 450 km. The readings' correlation is usually observed at about five neighboring latitudes which is equivalent to the characteristic dimension of albedo peaks of $\sim$ 2 to 3 thousand km.

It should be mentioned that the dimensions of inhomogeneities in several thousand kilometers are also characteristic of meteorological conditions and of large spots of night airglow [6]. The coincidence of these values makes it possible to assume that, despite the fact that the above mentioned events are not similar, the formation of inhomogeneities is connected in each of these events with a unified circulation process in the atmosphere.

In our first experiment of April 1965, the inhomogeneities in the distribution of ozone with the above characteristic dimensions were also observed, but they showed a worse recurrence, thus a lesser stability. A vast region with decreased ozone concentration was observed in this experiment simultaneously with these "small" inhomogeneities (Fig.2, region a). The characteristic dimension of this region is $\sim$ 10000 km, which is near the dimension of the Earth's surface illuminated by the Sun. The observed decrease in ozone concentration in this region is of about 30 percent. This decrease was also observed by us on the second day of the experiment of 18 April 1965, but its dimension was somewhat decreased, its center being displaced westward by some 2000 - 3000 km. It was practically invisible on 19 April. Such a large dimension rules out its consideration as a standard inhomogeneity and leads us to assume that it appeared as a result of globe influence of factors alien to the zone.

It may be noted, in particular, that the observations of this depression on 17 April began simultaneously with the first phase of the sudden commencement of a magnetic storm. (This dependence of the planetary Ap-index is indicated in Fig.2). However, the main phase of the magnetic storm with a substantially higher value of A_p-index was not attended by considerable changes in the spectrophotometer readings.

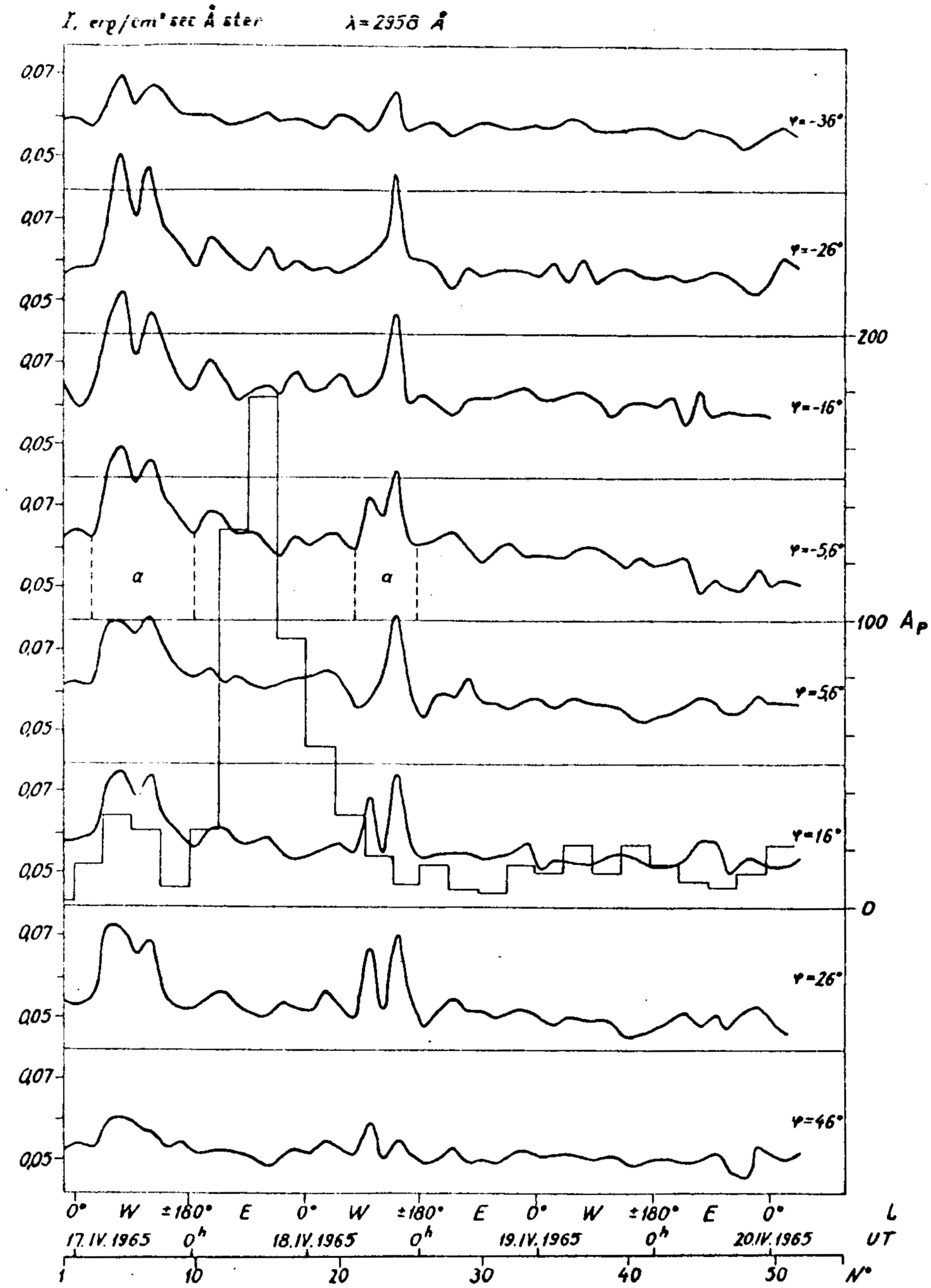

Fig.2. Dependence of the intensity in absolute units for the 2958 A wavelength at various latitudes ϕ on the number N of orbits (lower scale), U.T. (middle scale) and geographic longitude L (upper scale). Exp. of April 1965.

In order to determine more accurately the ozone content, it is expedient not to use a single wavelength, but practically the total spectrum, over which our resolution makes it reasonable to perform measurements at a frequency not greater than in 5 A increments.

Fig.3 shows several atmospheric spectra obtained for various latitudes. These spectra are generally similar to the spectra of solar radiation, although they are weakened by ozone absorption which varies with wavelength. At the shortwave side the spectra are broken at the threshold signal of 0.0025 erg/ /cm² sec A sterad.

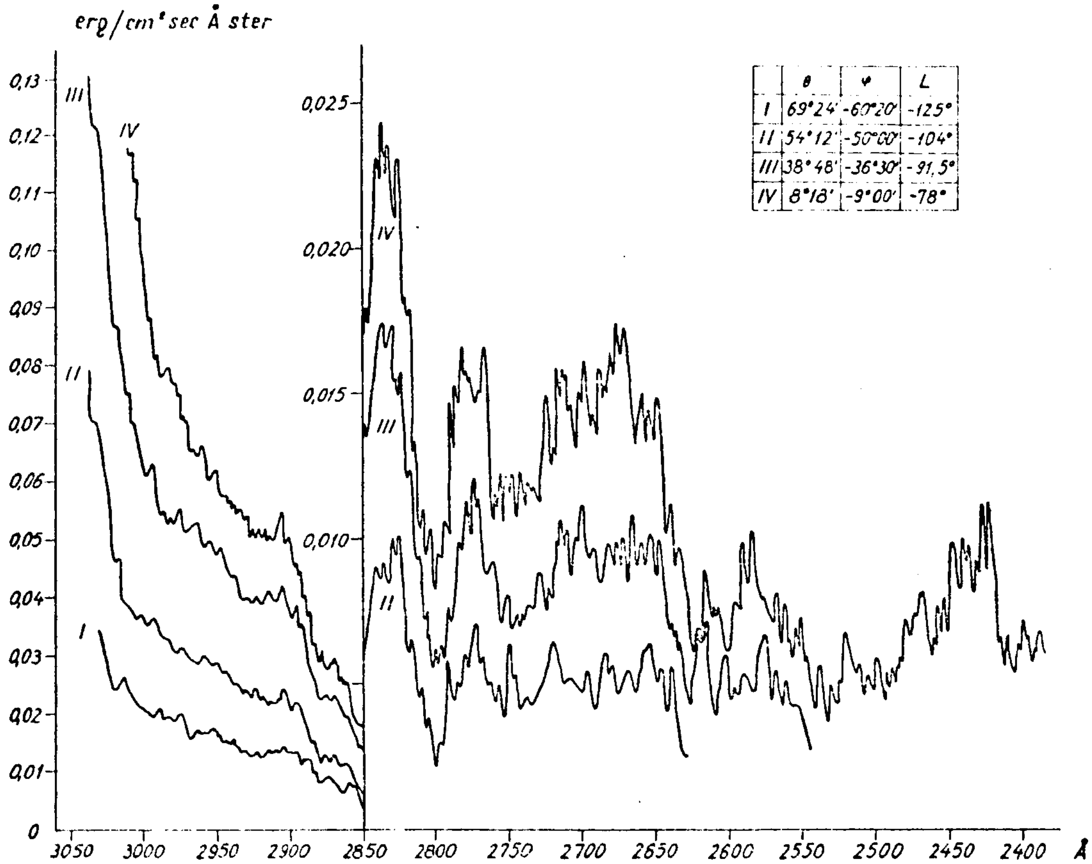

Fig.3. Distribution of intensity in the spectrum of the Earth's atmosphere as a function of Sun's zenithal angle θ, of the geographic latitude ϕ and longitude L.

It may be seen from these diagrams that the intensity varies for different wavelengths according to a complex law with the variation of point latitude and of the zenithal angle of the Sun. This is due to the change in the conditions of atmosphere illumination and also to latitude dependence of ozone content in the Earth's atmosphere.

Each spectrum was used to calculate the ozone content at the point where a spectrum was obtained, and after this the latitude dependence was found of ozone content in the Earth's upper atmosphere.

It was shown in [5, 7] that the determination of the vertical distribution of ozone in the Earth's upper atmosphere by means of satellites is reduced to the solution of the Laplace integral equation

$$R(k) = \int_0^\infty e^{-kx} \frac{dP(x)}{dx} dx; \qquad (1)$$

where $k = k'(1 + \sec\theta)$, k' is the ozone absorption coefficient in cm^{-1} [7], θ is the zenithal angle of the Sun, P is the atmosphere mass measured in cm at standard atmospheric pressure, higher than a certain level determined by the altitude h, x is the total quantity of ozone in the same units, higher than the same level.

The problem consists in determining from the experimentally known function $R(k)$ the unknown function $dP(x)/dx$. The solution thus found makes it possible to determine the dependence of P on $\underline{x}$ and hence, having known the dependence of P on $\underline{h}$, to find the dependence of $\underline{x}$ on $\underline{h}$. The approximation of $R(k)$ by the function

$$R(k) = \frac{A}{k + a} + \frac{B}{k - b} \qquad (2)$$

where $\underline{b}$ is positive and smaller than the lower limit of K, is used in the present work.(applying the method elaborated by one of the authors -V. A. Iozenas).

The 2770 - 2980 A wavelength range, which corresponds to the values $K = 25 \div 200\ cm^{-1}$, was chosen for the solution of this problem. The values of function $R(k)$ were determined for 43 points by measuring the intensity in the spectra with an increment of 5 A. With such a choice of wavelength range the depth to which the solar radiation penetrates into the atnosphere is sufficient for determining the amount of ozone above the ozone maximum and, at the same time, the influence of the lower atmosphere not counted as yet.

The solution of the Laplace integral equation has the form

$$\frac{dP(x)}{dx} = Ae^{-ax} + Be^{bx} \qquad (3)$$

or

$$P(x) = \frac{A}{a}(1 - e^{-ax}) + \frac{B}{b}(e^{bx} - 1) \qquad (4)$$

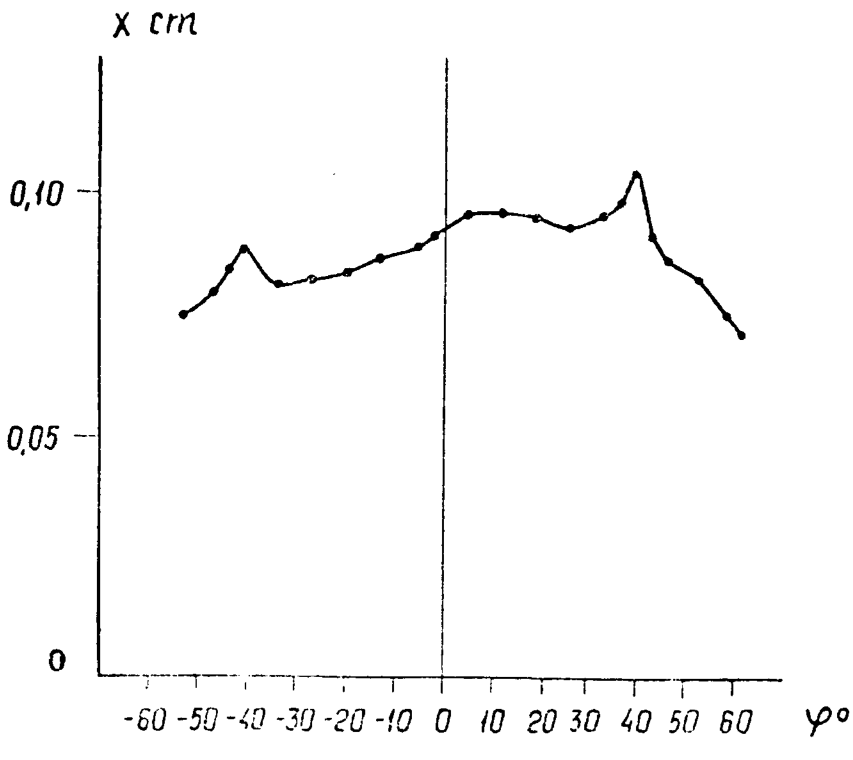

Fig. 4.

Latitude dependence of the quantity of ozone measured above 25 km in cm STP

Fig.4 illustrates the results of calculations of the latitude dependence of the quantity of ozone above 25 km (which corresponds to $P = 20 \cdot 10^3$ cm) for one of the satellite orbits.

It may be seen from the above diagrams that the quantity of ozone in the upper atmosphere is decreasing toward high latitudes, which agrees with the theoretical calculations of [8, 9]. The quantitative dependence coincides well with the data from U.S.A. ozone soundings for North America [10]. At the same time some asymmetry in the distribution of ozone is shown in the diagram for the Southern and Northern hemispheres with the center of gravity in the Northern hemisphere; this may be linked with the peak in ozone content in Northern hemisphere in April. The increase in the amount of ozone at latitudes $\sim 40°$ is likely related to the secondary ozone peak at high latitude observed there [11].

***** THE END *****

REFERENCES

1. A. I. LEBEDINSKIY, V. A. KRASNOPOL'SKIY, A. P. KUZ'MIN, V. A. IOZENAS. Issl. Kosmicheskogo Prostranstva, "Nauka", 77, MOSKVA, 1965.
2. G. F. SITNIK. Astronomicheskiy Zhurnal, No.4, 1962.
3. V. A. KRASNOPOL'SKIY, A. P. KUZNETSOV, A. I. LEBEDINSKIY, Geom. i Aeronom. 6, No.2, 1966.
4. A. I. LEBEDINSKIY, V. A. IOZENAS, V. A. KRASNOPOL'SKIY, A. P. KUZNETSOV. Proc. COSPAR VII, Vienna 1966.
5. V. A. KRASNOPOL'SKIY. Geom. i Aeronomiya, 6, No.2, Moscow 1966.
6. F. E. ROACH, E. TANDBERG-HANSSEN, L. R. MEGILL. J.Atm. & Terr.Phys. 113, 1958.
7. S. TWOMEY. J. Geophys. Res., 66, 2153, 1961.
8. H. K. PAETZOLD, UMSHOW, 53, No.23, 715-717, 1953.
9. ...*
10. S. WAYNE, Th. R. HERRING, T. R. BORDEN. AFCRL-64-30 (III), Envir. Res. Papers, No.133, August 1965.
11. BAZHKOV R. D. Physical Department of Moscow State University, Moscow 1964.

---

* Ref. [9] is missing in the preprint.

CONTRACT No.NAS-5-12487
VOLT TECHNICAL CORPORATION
1145 - 19th St.NW
WASHINGTON D.C. 20036
Telephones: 223-6700; 223-4930.

Prepared by ANDRE L. BRICHANT

from Conference Preprint

14 August 1967